Demonstration of an SDN Based Monitoring Framework for Converged Packet and Optical Networks Analytics

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Abstract: An SDN based monitoring framework is proposed and demonstrated to aggregate multi-layer monitoring information and enable end-to-end network analytics for converged packet and optical networks. New network functions are demonstrated with the proposed framework.
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1. Introduction

Analytics of network monitoring data help to address many important operational problems, especially in multi-layer and multi-technology network scenarios. Nowadays, there is a huge interest on how to merge network monitoring and data analytics concepts to optimize network utilization and maintain quality of transmission (QoT) in a network. However, the way to improve such unpredictable infrastructure are still under discussion.

Network monitoing provides information about network hardware, link transmission performance, and quality of service (QoS) with monitoring technologies in different layers of networking. In addition, the architecture-on-demand (AoD) programmable optical nodes, which enable network function programmability [1], can potentially provide ubiquitous power monitoring into optical networks. By combing ubiquitous power monitoring and other monitoring at optical layer with monitoring at electronic packet transport at the edge of the network, an end-to-end network analytics can be provided for efficient and optimized global decision-making. A Software Defined Network (SDN) framework is the ideal technology for aggregating all the monitoring information from different technology layers to a centralized monitoring hub, and setting up a network diagnostic tool. With the diagnostic tool, the SDN control plane can configure the underlying optical networks more intelligently and reconfigure or re-plan the optical networks according to the changes in optical layer as well as electronic packet layer. In addition, the network diagnostic tool with the capability of programming of monitoring resource, makes “debugging” of optical network possible.

In this paper, we propose a novel SDN based monitoring analytics framework to handle the exposed packet over optical monitoring information and initiate meaningful actions to improve/maintain/recover the QoT for end-to-end network services. With the multi-layer monitoring enabled network diagnostic tool, the SDN control plane could obtain the state of the network topology and network device before it setup the requested optical interconnection, monitored information when the optical link is setup, and optical debugging information for further recovery after network failure occurs. We demonstrated several network analytics functions supported by the multi-layer monitoring enabled network diagnostic tool, including network optimization, network re-planning and network debugging and restoration. The experimental demonstrations confirmed that the monitoring information would help the control plane to configure the network in a hardware-efficient way and improve the network reliability.

2. Architecture of SDN-based monitoring analytic framework

In this work we define and develop an architecture for network monitoring enabled control plane applications, which support data analytics network functions. The architecture provides a generic methodology that enables network diagnostic tool with multilayer monitoring technologies. Fig. 1(a) shows our generic approach for the SDN-enabled monitoring control plane. We use OpenDaylight (ODL) as a gateway to gather information from the packet domain and configure multi-layer networks using OpenFlow extensions for optical nodes. The monitoring application gathers information from the controller and from the optical domain, and act to setup configurations through ODL. Such approach will handle both information from packet and optical networks. The architecture of monitoring application (see Fig. 1(b)) is composed by a monitoring data analytic core, the users’ gateway to handle users’ requests, a monitoring data collector and a configuration manager. The analytic framework operates based on the concepts of the filter chain (see Table 1) and actions pool. A set of configurable monitoring data filters is defined by the user, and appended into a chain which is run regularly by the core based on a predefined timer. A monitoring data filter is defined in this test as a set of attributes: filter (power, OSNR, data rate, etc.), threshold (numerical number), type (maximum or minimum), ids or resources (eg. list of ports) and an action. Fig. 1(c) shows the flowchart associated to the defined

Table 1 Example of Filter Chain

Technology	Filter	Threshold	Type	Ports	Action
Optical	Power	-10	Max	196,351,353	Attenuate
Optical	Power	-15	Min	all	Recover
Packet	rate	1G	Max	5,6	Allocate
…	…	…	…	…	…

monitoring application. Based on the users' data (filters enabled) coming to the gateway and the network data retrieved by the collector, the core process the filters that run the different configuration actions into the network.

The proposed analytic framework can sit on top of an SDN controller or can be integrated within an SDN controller. The proposed architecture is flexible, easy to be extended and configurable dynamically by the network user (e.g. infrastructure provider) through an exposed RESTful northbound interface (NBI).

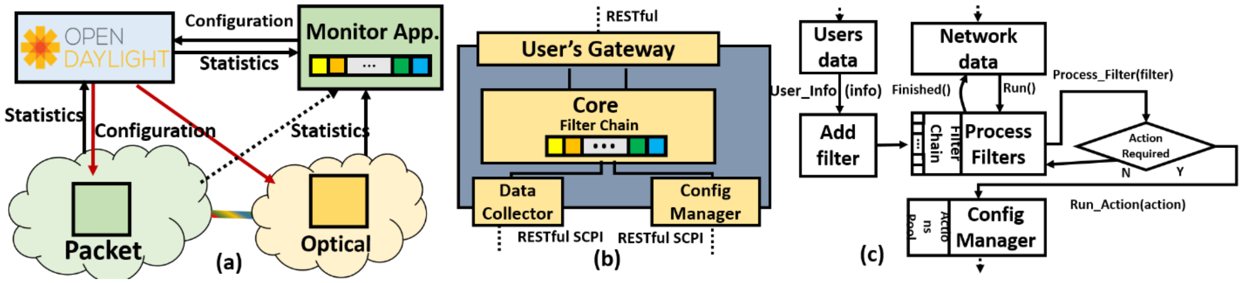

Fig.1 (a)Generic approach for the SDN-enabled monitoring control plane; (b)Architecture for network monitoring application; (c)Flowchart of the defined monitoring application

3. Experimental Demonstrations

(1) Converged optical and packet network analytics based on with both layer-2 monitoring and OSNR monitoring enabling QoS recovery. In border node, the packet traffic from Ethernet clients are aggregated and converted to OCS traffic for spectral-efficient transmission. With packet traffic monitoring and optical monitoring, the network can be optimized based on the incoming client traffic and characteristics of the transmission link. As shown in Fig.2, an FPGA-based OPS/OCS interface converts Ethernet traffic to OCS traffic [2]. The packet monitoring information is used to estimate the traffic capacity and thus to choose the required modulation format of the QPSK/16QAM multi-format transmitter. In OCS, receiver-side OSNR monitoring based on error-vector-magnitude (EVM) provides in-band OSNR information. The monitoring application processes the two-layer monitoring information to detect OSNR degradation or incoming traffic change, and then trigger the SDN control plane to reconfigure optical link to adopt a lower order modulation format, or to choose another link.

Fig.2 shows the experimental setup for OCS domain. At node A, 10 carriers with QPSK or 16QAM signals are launched into the optical network. The 28Gbaud QPSK/16QAM transmitter with a central wavelength of 1548.9nm is connected to the packet domain with an integrated OPS/OCS interface. The signals are transmitted 175km from node A, through node B, then to node D, and demultiplexed at node D for coherent reception. EVM-based OSNR monitor is deployed at the coherent receiver.

ASE noise is added into the link between node A and B to emulate OSNR degradation. The initial modulation format of the link is 16QAM at 28Gbaud. By adding more ASE noise in the link, the monitored OSNR will decrease to a threshold of 23dB. Then the monitor application notifies the SDN Controller to reconfigure the link. In scenario 1, the QPSK/16QAM TX reconfigures its modulation format from 16QAM to QPSK, to provide a guaranteed bitrate with only half of original bitrate. Recovered constellation diagrams are shown in Fig.2(d) for the 16QAM and Fig.2(e) for the QPSK signal. In scenario 2, the SDN controller reconfigures the optical path to node A to node D directly with

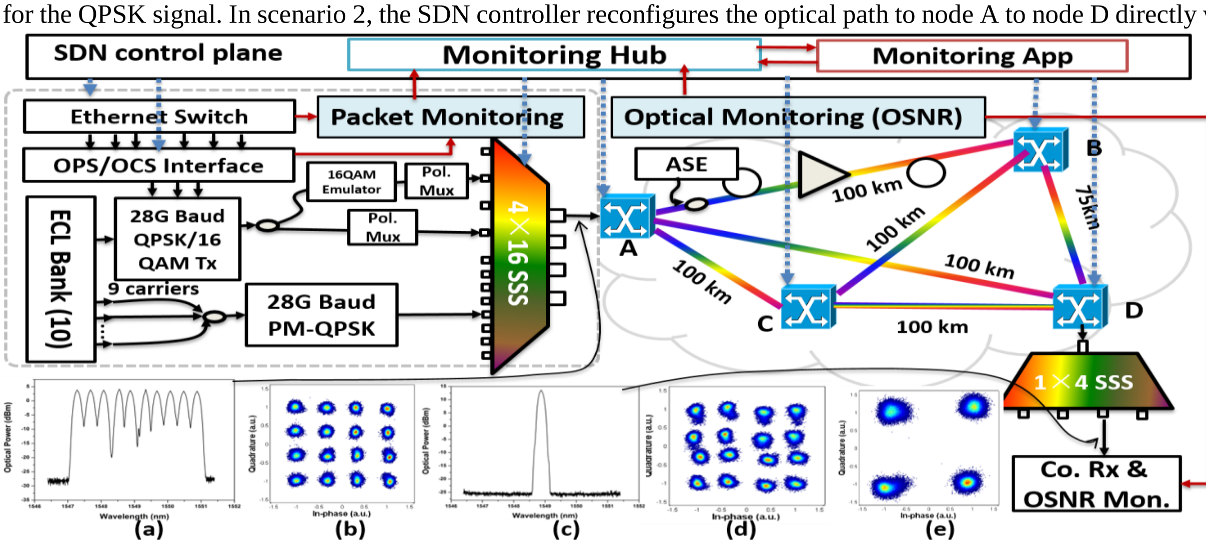

Fig. 2 Experimental demonstration of QoS recovery with packet and optical monitoring information

a reduced distance link.

(2) Optical network data analytics empowered by an architecture programmable optical node. Architecture on Demand (AoD) based optical node enables network function and node architecture programmability. In addition, the AoD based node can provide ubiquitous power monitoring with integrated power monitor, as both input and output port of all the devices are accessible and managed by the AoD fiber switch. The ubiquitous power monitoring provided useful information for the optical connection. Two cases show that the ubiquitous power monitoring enable new functions in AoD-based optical nodes.

***Enable power equalization at any combing device*:** As shown in Fig.3, power equalization can be achieved at any combing device in optical node, with integrated attenuators and power monitors in the AoD fiber switch. The equalization application processed the power monitoring information, and triggered the SDN controller to configure the integrated attenuators at the input ports if power deviation exceeded a threshold of 2 dB. The optical spectra of the combined signal with/without power equalization are shown in Fig.3(a). The captured SDN messages are shown in Fig.3 (b). For multiple channel signals, the power deviation should also consider the channel occupations. Without resorting to the last-stage SSS (spectrum selective switch), the power equalization at all the combing device will improve energy consumption and node reliability.

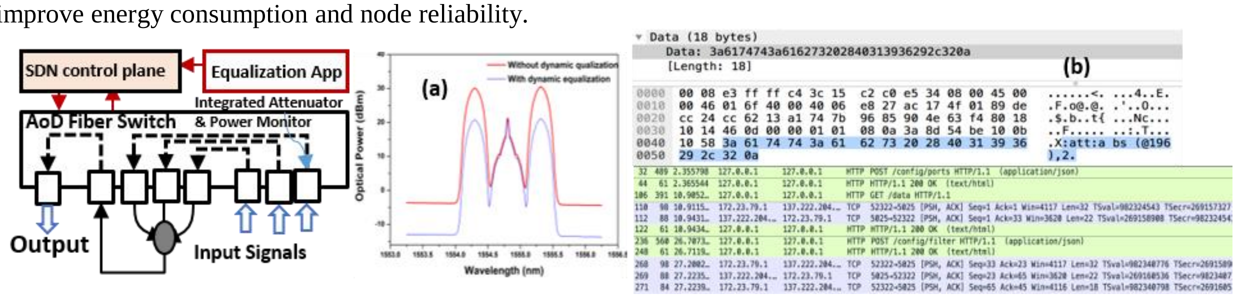

Fig.3 (a) Power equalization enabled by ubiquitous optical power monitoring. (b)Captured SDN messages.

Enabling network debugging and auto-restoration: Ubiquitous power monitoring provides input and output powers of all the components in the link. As shown in Fig.4, an optical channel is setup through three AoD-based optical nodes. The AoD fiber switch is omitted for simplicity. The link passes several SSSs, EDFAs and optical links. All the connection points, indicated with star symbols, are monitored and managed by the AoD fiber switch. In our demonstration a network failure occurs when the last EDFA is broken. The detecting signal loss will trigger the debugging application to check the insertion loss of all the connected components in the link. By comparing to the reference value, the debugging application located the broken component, as indicated the last EDFA in the link is down. Then the AoD based node checks the optical component inventory to find another available EDFA and replaced the broken EDFA by changing the AoD configuration. After the replacement, the network failure is restored. The constellation for the 28GBaud PM-QPSK signal after transmitting over 275km is shown in the inset of Fig. 4. The auto-restoration feature will improve the robustness of optical network and also decrease the network operation cost.

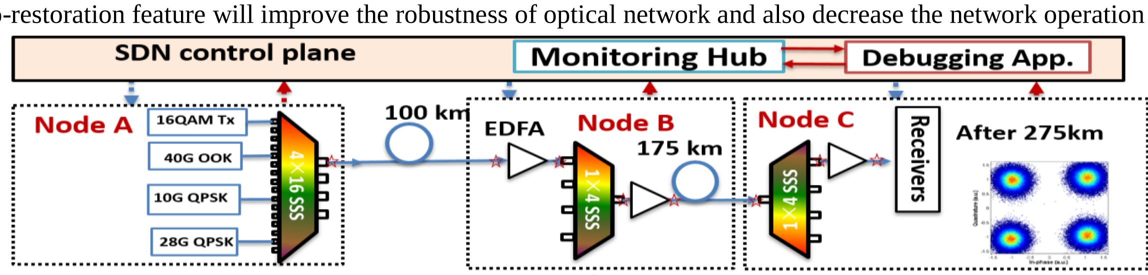

Fig. 4 Experimental setup of network auto-restoration

4. Conclusion

We propose an SDN based monitoring framework for converged packet and optical networks analytics. Several demonstrations confirmed monitoring information can help to optimize the network utilization and enable new network functions.

Acknowledgement

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